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Changes in heat transfer coefficients in Poland and their impact on energy demand - an environmental and economic assessment

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ABSTRACT

The percentage share of final energy consumption in the Polish residential sector, in relation to the final energy consumption value in all sectors of the economy, stands at about 30%. Thermal modernization and thermal insulation of both existing and new construction substances in order to reduce the building's energy demand for heating is economically valid. Therefore, continuous regulatory amendments within the capacity of reducing the heat transfer coefficient *U* of different building elements are desirable. This article examines the economic and ecological benefits which are a result of the changes that took place in the value of the heat transfer coefficient in the regulations. These benefits apply to both new construction and building renovations. The LCA (life cycle assessment) methodology was used for the assessment of ecological benefits. The normative values of the heat transfer coefficient, which are to be implemented in 2017 and 2021, are economically and ecologically justifiable in the Polish conditions. This pertains to thermal insulation materials, applied heating systems and climate conditions. The payback period of economic costs associated with denser thermal insulation (from the requirements of 2014 until 2021) will take place within 2–11 years. The environmental costs will return within the range of 2–6 years, depending on the specific heat source used within the structure.

1. Introduction

The European Union focuses much attention to economic development which is based on the paradigm of sustainable development. The European Commission puts great emphasis on reducing atmospheric greenhouse gas emissions [1]. Eight years ago, (January 2007) the European Commission proposed a so-called climate and energy package, which was adopted by the European Parliament in 2008. This package requires all member states of the European Union to [2–4]:

- reduce greenhouse gas emissions by a minimum of 20% in 2020 when compared to the 1990 baseline, as well as to reduce greenhouse gas emissions in the EU by 30% in 2030. This should take place under conditions that the global agreement of the reduction of greenhouse gases will be obtained;
- increase the energy share of renewable sources in final energy consumption up to 20% in 2020, including a 10% share of biofuels in propellant fuel consumption (Poland received a lower requirement proposal (by 5% points –15%) [5];
- increase energy efficiency by 20% by 2020 when compared to the demand forecast for fuel and energy.

In order to implement the climate and energy package in the European Union, a number of legislative documents were adopted and established with the aim of achieving the assumed objectives. These include:

- the European Parliament and European Council Directive 2009/29/EC of 23 April 2009 amending the Directive 2003/87/EC as to improve and extend the community trading scheme for greenhouse gas emissions;
- the European Parliament and European Council Directive 2009/31/EC of 23 April 2009 on the geological storage of carbon dioxide amending the Council Directive 85/337/EEC,
- Euratom,
- the European Parliament and European Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006;
- the European Parliament and European Council Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives

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Nomenclature

d	thickness of the thermal insulation layer [m]
j	number of wall type
K_c	cost of generated heat [PLN/kWh]
K_e	LCA result of obtaining 1 kWh of thermal energy [Pt/kWh]
K_l	LCA analysis result of thermal insulation material [Pt/m^3]
K_m	cost of thermal insulation material [PLN/m^3]
n	number of years of thermal insulation use
p_u	usable area of the building [m^2]
p_w	surface area of the wall [m^2]
R_0	thermal resistance [m^{2}K/W]
r	real annual interest rate [%]
s	real annual heating cost growth [%]
U	heat transfer coefficient [W/m^{2}K]
λ	thermal conductivity coefficient [W/mK]
LCA	life cycle assessment
NPV	net present value

2001/77/EC and 2003/30/EC;

- the European Parliament and European Council Directive 2010/31/EC of 19 May 2010 on the energy performance of buildings;
- the European Parliament and European Council Directive 2010/30/EC of 19 May 2010 on the indication of the consumption of energy and other resources by energy-related products by labelling and providing standard product information [6].

In January 2014, the European Commission proposed another "new" climate and energy package 2030. It is comprised of two main objectives: a reduction of greenhouse gas emissions (GHG) by 2030, by 40% below the level of 1990, as well as to at least 27% in the production of energy from renewable sources combined with an increase of this energy in the overall energy balance [7].

Before the accession to the European Union (prior to 2004), final energy consumption in Poland was clearly at a level lower than that of the past decade (see Table 1). Since 2006, final energy consumption was steadily increasing - reaching its peak value in 2010. This rise was the result of a significant increase in the pace of the economic development of the country. The residential sector, according to the McKinsey curve, should experience the lowest cost of energy efficiency improvements [8]. We have been observing an upward trend in this sector, with the highest attribute being in 2010. It should be noted that the value of energy consumption in the residential sector has significantly increased since 2005. The percentage share of final energy consumption in the residential sector, in relation to the final energy consumption in all sectors of the economy, stands at about 30% (see Table 1).

Due to high final energy consumption in the residential sector, said sector is believed to have the most economically reasonable potential to improve energy efficiency. Thermal modernization and thermal insulation of existing and new construction substances are seen as economically justified projects. Hence, continuous regulatory amendments in order to reduce the heat transfer coefficient U of the various elements of the building are desirable.

The aim of this paper is to examine the economic and environmental benefits resulting from changes in the value of the heat transfer coefficient in regulations in relation to the construction and renovation of buildings. So far, the literature has not yet analysed both types of benefits when applied to the construction sector. Pikas and others [10] only assess the economic benefits of the renovation of residential buildings in the context of improving energy efficiency. The analyses of both types of benefits take place in many scientific articles [11–14], but these analyses are based on different methodologies of evaluation and relate to other sectors of human activity. The verification of standard values of the heat transfer coefficient in terms of economic benefits is particularly important in the context of the provisions of Art. 4 of Directive 2010/31/EU - "*The member state shall not be required to set minimum energy performance requirements which are not economically cost-effective over the estimated economic life cycle*" [15]. Another aim of this article is to compare the values of heat transfer coefficients and their changes over time with another country which has a climate similar to Poland's. In this case, Germany was selected. The selection of the country for the purpose of comparing the current U-values in a given period, was made based on the European map of heating degree days (HDD) [16]. The analysis includes calculations of the energy demand of the building on the basis of former, existing and recommended future values of the heat transfer coefficient U.

In Section 2 of the article, changes in the regulations that apply to the heat transfer coefficient of the building walls were analysed. The next section describes the examined building. The LCA analysis (see Section 4) was used to assess the influence of the thermal insulation investments on the environment. Another section proposes the methodology of economic and ecological assessment of the thermal insulation of building walls. Section 6 presents the outcomes of the conducted analyses. Lastly, the most important conclusions, which apply to the energy demand of buildings and the economic and ecological benefits of thermal insulation, were given.

2. Origins of changes in the value of heat transfer coefficients of different walls in Poland and Germany

The value of standard heat transfer coefficients of building walls U [W/m^{2}K] (formerly k) is crucial to the future energy demand of the building. The coefficient $U = (R_o + d / \lambda)^{-1}$ of a particular wall depends on the thermal resistance of diffusion through the wall without the thermal insulation layer – R_o [m^{2}K/W], the thickness of the thermal insulation layer – d [m] and the thermal conductivity coefficient of the material constituting thermal insulation – λ [W/(mK)]. Reducing the value of U coefficient results in a reduction in the energy demand of the building. The regulations of the member states of the European Union try to keep up with rapidly changing European regulations and changing economic factors. The latter are significantly connected to the aforementioned, as they contribute to the determination at the lower level of the economic optimum for thermal insulation projects. Obviously, a factor related to the rise in the prices of energy carriers on the global markets is also not without significance for the economic optimum value of these projects.

Table 1
Final energy consumption in Poland in 1000 toe.
Source: [9]

	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Final energy consumption	59,949	55,745	56,164	54,595	56,081	58,063	58,328	60,937	61,837	62,205	61,153	66,332	63,870	63,635
Final energy consumption in the residential sector	17,841	17,194	18,799	17,770	17,756	17,769	18,346	19,309	18,371	18,652	18,862	21,126	19,007	19,601